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Lithium

UNITED STATES DEPARTMENT OF THE INTERIOR

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This publication is a chapter from the current Bureau of Mines Minerals Yearbook, comprising *Volume I, Metals and Minerals; Volume II, Area Reports: Domestic; Volume III, Area Reports: International.* The separate volumes of the Yearbook are sold by the Superintendent of Documents, Washington, D.C. 20402.

Lithium

By Joyce A. Ober[1]

The United States remained the world's largest producer and consumer of lithium minerals and chemicals, although domestic production decreased. Imports of lithium mineral concentrates and lithium chemicals increased, essentially replacing most of the lost domestic production and causing a slight increase in estimated consumption over the level of 1986. The budding recovery of the domestic aluminum industry from its recent slump had the effect of increasing demand for lithium carbonate near year-end. Exports remained the same based on contained lithium and producers' stocks decreased slightly. World production experienced little change.

Domestic Data Coverage.—Domestic production data for lithium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the two operations to which a survey request was sent, both responded, representing 100% of total production. However, production and stock data were withheld from publication to avoid disclosing company proprietary data.

Legislation and Government Programs.—The General Services Administration reported sales of 52,000 pounds of lithium hydroxide monohydrate, valued at $43,000 from excess stocks of the U.S. Department of Energy (DOE). The stockpile originally contained 46,000 short tons of material, about 75% of which was depleted of lithium 6 and possibly contained 8 to 9 parts per million of mercury. The remainder of the material in the DOE account, 79,865,549 pounds, is designated for disposal.

Table 1.—Salient lithium statistics

(Short tons of contained lithium)

	1983	1984	1985	1986	1987
United States:					
Production[1]	W	W	W	W	W
Producers' stock changes[3]	W	W	W	W	W
Imports[2]	35	90	410	700	900
Shipments of Government stockpile surplus[3]	1	1	1	2	4
Supply[1,4]	6,000	6,600	5,500	4,100	4,000
Supply[e,5]	4,800	6,100	5,000	3,500	3,200
Exports[e,6]	2,600	2,900	2,500	2,000	2,000
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,200	3,200	2,500	2,600	2,700
Rest of world: Production[e,1]	r1,800	r2,500	r3,300	r3,400	3,500

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Mineral concentrate and carbonate.

[2]Compounds, concentrate, ores, and metal.

[3]Lithium hydroxide monohydrate.

[4]Production minus inventory increase.

[5]Based primarily on monitoring at the carbonate stage and assuming a 17 [illegible]thium loss during conversion of concentrate to chemicals.

[6]Compounds.

DOMESTIC PRODUCTION

Two companies continued to produce lithium products in the United States. Lithium Corp. of America, (Lithco), a subsidiary of FMC Corp., mined spodumene, a lithium ore, from pegmatite dikes near Bessemer City, NC. The company produced lithium carbonate and downstream lithium compounds, including some organic lithium compounds, at a chemical plant near the mine. Foote Mineral Co., 87.5% owned by Newmont Mining Corp., recovered lithium carbonate from a subsurface brine deposit in Silver Peak, NV. Foote's lithium carbonate operation at Kings Mountain, NC, remained inactive throughout 1987, but some production of marketable ore concentrates continued. At yearend, Foote announced an agreement with Cyprus Minerals Co. to enter a cash merger with a new Cyprus subsidiary. The merger will be completed early in 1988.[2]

Foote operated processing facilities for downstream lithium products and metal in Frazer, PA; Sunbright, VA; and New Johnsonville, TN.

CONSUMPTION AND USES

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries were the major consumers of lithium minerals and chemicals. These markets were primarily related to transportation, i.e., the aircraft and automotive industries. Ceramics and glass were also used in industrial and consumer applications. Estimated domestic consumption increased slightly, but U.S. production decreased. Imported lithium ores continued to replace lithium carbonate in some ceramics and glass applications.

The aluminum industry, which began to recover from its slump, maintained its edge as the leading end use for lithium in the United States. Lithium carbonate is added to the cryolite bath in aluminum potlines where it is converted to lithium fluoride. The lithium fluoride lowers the melting point of the bath, allowing a lower operating temperature for the potline and increasing the electrical conductivity of the bath. Operators use these factors to increase production, reduce power consumption, or increase current efficiency.

The second largest end use, the addition of lithium chemicals and ore concentrates to ceramics and glass manufacturing processes, is approaching that of the aluminum industry in volume of lithium consumption. Lithium additions, in the form of carbonate and mineral concentrates, lower process melting points, reduce the coefficient of thermal expansion and the viscosity, and eliminate the use of more toxic chemicals. The manufacture of thermal-shock-resistant cookware consumed the majority of lithium used in the ceramics and glass industry. Use of low-iron petalite and spodumene, two lithium ores, increased as a source of the lithium used to improve the physical properties of container and bottle glass, as well as a source of alumina (Al_2O_3), another important component of the glass. Lithium is being used increasingly in container and bottle glass, enabling glass manufacturers to produce lighter weight, thinner walled products.

The third largest end use for lithium was in the multipurpose grease industry. Lithium-based greases are favored because they retain their lubricating properties over a wide temperature range; have good resistance to water, oxidation, and hardening; and if liquefied, form a stable grease on cooling. These greases continued to be utilized in military, industrial, automotive, aircraft, and marine applications.

Lithium batteries represent an end use with the potential for dramatic growth. The 9-volt lithium-manganese dioxide battery announced by Eastman Kodak Co. in 1986, appeared on the consumer market in late 1987, indicating that lithium batteries had moved from specialty applications into everyday use. Although they represent a small percentage of total lithium consumption, sales of these batteries are expected to grow 13% per year until at least 1996.[3] Lithium batteries offer improved performance over the more traditional alkaline batteries, at a slightly higher cost. Lithium batteries have been used in cameras, microcomputers, and watches, and more recently in small appliances, electronic games, and toys. Large lithium batteries have been used in military applications.

Aircraft manufacturers in several countries have experimented with aluminum-

lithium alloys as the material for wing and fuselage skin. Several U.S. companies have announced that they will use these alloys in their new airline models.[4] Use of aluminum-lithium alloys can reduce the weight of the aircraft by more than 10%, allowing significant fuel savings over the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, are of interest to the aircraft and aerospace industry because of their reduced density and superior corrosion resistance compared with that of conventional aluminum alloys. These alloys face direct competition, however, from composite materials consisting of boron, graphite, or aramid fibers imbedded in plastic.

Small quantities of other lithium compounds were important to many industries. Butyllithium was used as a catalyst in synthetic rubber production. Lithium chloride and lithium bromide were used in industrial air-conditioning systems, commercial dehumidification systems, and in the production of sophisticated textiles. Sanitizers for swimming pools, commercial glassware, and public restrooms contained lithium hypochlorite, as did dry bleach for commercial laundries. Patients diagnosed as suffering from manic-depressive mental disorders were prescribed medication containing a pharmaceutical grade of lithium carbonate. Lithium metal was used as a scavenger to remove impurities from copper and bronze, and anhydrous lithium chloride was used in fluxes for hard-to-weld metals such as steel alloys and aluminum.

STOCKS

Yearend producers' stocks of lithium carbonate and marketable ore decreased slightly.

PRICES

Both domestic lithium-producing companies announced price increases for their large-volume products, lithium carbonate and lithium hydroxide monohydrate, for the first time since 1984. These increases were prompted by the fact that world production capacity for lithium reflected demand more closely than it had in recent years. This situation was due to the continued shutdown of operations at Kings Mountain, NC. In addition, the North American aluminum industry began to recover from its slump, promising an increase in demand for lithium carbonate from that sector. Additional price increases, averaging about 5%, were announced for most other lithium compounds.

Table 2.—Domestic yearend producers' average prices of lithium and lithium compounds

(Dollars per pound)

	1986	1987
Lithium bromide, 54% brine: 2,268-pound lots, delivered in drums	4.24	4.33
Lithium carbonate, technical: Truckload lots, delivered	1.50	1.55
Lithium chloride, anhydrous, technical: Truckload lots, delivered	3.49	3.66
Lithium fluoride	5.12	5.38
Lithium hydroxide monohydrate: Truckload lots, delivered	1.93	1.97
Lithium metal ingot, battery-grade: 1,000-pound lots, f.o.b.	35.10	37.68
Lithium metal ingot, standard-grade: 1,000-pound lots, f.o.b.	24.20	25.45
Lithium sulfate, anhydrous	3.21	3.51
N-butyllithium in n-hexane (15%): 3,000-pound lots, delivered	15.88	15.88

Source: U.S. lithium producers.

FOREIGN TRADE

In 1987, U.S. exports of lithium carbonate increased 10%, exports of lithium hydroxide remained about the same, and exports of other lithium compounds decreased 13%. U.S. imports for consumption of lithium ores increased 36% over the figures reported in 1986, and imports of lithium compounds increased 10%. Ninety-four percent of these imports were from Foote's joint venture with the Government of Chile at the Salar de Atacama. Lithium metal imports increased over 500%, which reflected

growing demand for lithium batteries and alloys. Imports of lithium salts were also up significantly, but the 194% increase represents less than 1% of total lithium imports in terms of contained lithium.

Table 3.—U.S. exports of lithium chemicals, by compound and country

Compound and country	1986		1987	
	Gross weight (pounds)	Value	Gross weight (pounds)	Value
Lithium carbonate:				
Australia	72,220	$88,784	144,000	$201,240
Brazil	440	3,498	6,600	10,416
Canada	1,470,149	2,391,197	908,586	1,264,928
France	118,646	170,441		
Germany, Federal Republic of	5,367,455	6,766,826	5,239,635	6,377,717
Hong Kong	38,891	51,764	1,067	1,600
India	25,877	72,943	14,722	23,569
Japan	2,180,837	3,129,384	2,703,248	3,644,631
Korea, Republic of	141,680	212,927	196,433	281,307
Mexico	371,011	547,580	186,114	280,317
Netherlands	455,875	657,101	476,551	653,764
New Zealand	1,100	5,071	4,409	8,740
Singapore			23,491	35,236
South Africa, Republic of	46,300	69,210	39,600	64,740
Taiwan	361,518	484,591	431,403	615,576
United Kingdom	918,601	1,314,335	2,344,063	3,237,397
Venezuela	8,800	12,341	20,009	30,812
Zimbabwe			9,700	13,833
Total	11,579,310	15,977,901	12,749,551	16,750,809
Lithium hydroxide:				
Argentina	386,916	668,863	262,732	436,559
Australia	204,882	350,940	167,000	278,238
Austria	950	1,030		
Belgium	791	3,713		
Brazil	953,925	1,626,832	649,345	1,125,288
Canada	19,481	31,630	136,000	257,980
Chile	39,457	75,396	34,394	65,200
Colombia	12,400	24,012	47,550	82,786
Ecuador	17,623	32,160	39,688	72,468
France	44,000	77,400	44,000	66,002
Germany, Federal Republic of	923,425	1,609,230	1,079,765	1,755,831
Greece			3,307	7,335
Honduras	6,600	13,530	4,400	8,395
India	503,498	842,238	420,336	762,874
Indonesia	92,000	187,264	76,000	152,065
Israel	40,344	70,373	48,492	87,025
Italy	6,614	12,831		
Japan	1,459,124	2,690,737	1,135,087	2,043,074
Kenya	59,774	110,147	44,000	81,445
Korea, Republic of	203,987	338,728	240,293	389,534
Malaysia			8,818	15,432
Mexico	56,753	190,591	104,781	209,400
Netherlands	145,200	240,457	315,429	510,567
New Zealand	13,219	25,029	6,614	12,864
Pakistan	46,026	83,840	58,367	103,590
Peru	15,465	28,557	25,543	42,605
Philippines	45,000	74,360	50,325	91,460
Saudi Arabia			68,343	121,575
Singapore	88,148	160,264	70,437	121,662
South Africa, Republic of	139,360	246,716	206,271	352,096
Spain	44,000	79,200		
Sweden			44,000	64,626
Taiwan	78,421	125,798	41,902	141,995
Thailand	17,931	32,573	36,000	63,665
Turkey	85,800	149,292		
United Arab Emirates	5,292	9,633	37,239	65,313
United Kingdom	569,277	909,676	795,825	1,196,244
Uruguay	882	1,800		
Venezuela	44,092	79,360	87,291	168,018
Yugoslavia	16,000	26,651	15,000	32,326
Zimbabwe			26,400	47,366
Total	6,387,658	11,140,851	6,430,174	11,032,905
Other:				
Argentina	124	2,632	12,202	587,602
Australia	27,480	66,771	64,956	155,299
Belgium	39,379	34,353	12,720	12,466
Bermuda	9,813	40,856		
Bolivia	2,200	2,073		

Table 3.—U.S. exports of lithium chemicals, by compound and country —Continued

Compound and country	1986		1987	
	Gross weight (pounds)	Value	Gross weight (pounds)	Value
Other —Continued				
Brazil	40,610	$122,174	34,259	$144,542
Canada	472,393	912,150	840,024	1,336,830
China	1,200	1,428	11,000	20,624
Colombia	4,792	14,825	1,615	12,840
Costa Rica	1,000	1,520		
Denmark			¼	1,586
Finland	9,211	16,120		
France	122,773	291,491	48,624	128,216
Germany, Federal Republic of	338,142	1,466,270	175,230	240,100
Hong Kong	140	9,600		
India	3,388	17,035	40	1,600
Israel	2,432	49,095	1,548	8,451
Italy	1,512	1,036	10,062	24,523
Jamaica	14,890	36,422		
Japan	114,892	888,108	159,759	746,502
Jordan			1,704	1,879
Korea, Republic of	172,728	223,734	157,164	209,610
Mexico	181,155	420,718	534,796	1,463,046
Netherlands	321,200	488,612	66,000	97,662
Nigeria			73	4,440
Pakistan	20,041	41,157	12,042	31,835
Philippines			21,580	258,232
Saudi Arabia	75	12,588		
Singapore	27,829	56,470	3,399	19,969
South Africa, Republic of	21,287	50,962	298	3,986
Sweden			1,561	155,365
Switzerland	156	3,588		
Taiwan	8,927	43,404	31,487	97,666
United Arab Emirates			6,613	11,905
United Kingdom	1,126,018	2,657,074	474,780	1,157,173
Venezuela	5,978	11,861	4,758	23,038
Yugoslavia	551	75,742	486	105,080
Total	3,092,226	8,659,869	2,688,074	7,062,077

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of lithium-bearing materials, by commodity and country

Commodity and country	1986			1987		
	Gross weight (pounds)	Value (thousands)		Gross weight (pounds)	Value (thousands)	
		Customs	C.i.f.		Customs	C.i.f.
Lithium ores:						
Australia[1]	2,273,967	$247	$325	4,977,337	$491	$687
Brazil				30	1	2
Canada[1]	2,892,257	306	306	13,958,632	1,414	1,414
Japan				22	2	2
United Kingdom				496,000	57	57
Zimbabwe	21,488,181	2,639	2,985	16,914,565	1,627	1,825
Total	26,654,405	3,192	3,616	36,346,586	3,592	3,987
Lithium compounds:						
Belgium				132	4	4
Canada				55	1	1
Chile	4,125,042	5,239	5,525	4,347,930	4,845	5,121
China	5	2	2	4,409	6	8
France	12,200	3,161	3,178	6,013	593	588
Germany, Federal Republic of	51,787	330	342	34,014	249	257
Hong Kong				37,478	53	56
Japan	228	66	69	455	67	70
Switzerland				144,092	173	183
Taiwan				37,478	53	56
United Kingdom	381	49	50	6,129	130	131
Total	4,189,643	8,847	9,166	4,618,095	6,174	6,485

See footnote at end of table.

Table 4.—U.S. imports for consumption of lithium-bearing materials, by commodity and country —Continued

Commodity and country	1986			1987		
	Gross weight (pounds)	Value (thousands)		Gross weight (pounds)	Value (thousands)	
		Customs	C.i.f.		Customs	C.i.f.
Lithium salts:						
France	220	$8	$9	10,723	$9	$10
Germany, Federal Republic of	4,409	24	28			
Japan	50	2	2	3,288	27	29
United Kingdom	90	4	4			
Total	4,769	38	43	14,011	36	39
Lithium metal:						
France				3,340	7	8
Germany, Federal Republic of	4,333	24	25	10,482	21	23
Japan				50	2	3
United Kingdom				13,935	201	204
Total	4,333	24	25	27,807	231	238

[1]Spodumene concentrate.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

WORLD REVIEW

Argentina.—Construction of a chemical plant to recover lithium, magnesium, and potassium salts from the Salar del Rincón was scheduled to begin before yearend. This brine deposit is near Campo Quijano in the Salta Province.[5]

Bolivia.—Brine-harvesting and mining concessions have been requested from Complejo Industrial de Recursos Evaporíticos del Salar de Uyuni, as well as permission to build a pilot plant for treatment of the brines of the Salar de Uyuni. Industria Minera Tierra Ltda. requested these concessions and planned to produce borax, boric acid, lithium, and magnesium salts and derivatives from the deposit, which reportedly contains higher concentrations of lithium than similar deposits in Chile. The company has also identified another deposit with high lithium concentrations as an alternative concession to the Salar de Uyuni request.[6]

Brazil.—Cia. Brasileira de Litio neared completion of its 1,700-ton-per-year lithium carbonate plant near Aracuai in Minas Gerais. The new facility was intended to make Brazil self-sufficient in lithium production; exports of lithium carbonate are also planned. The plant was designed to produce lithium carbonate from spodumene. Minas Gerais has proven reserves of lithium ores of 810,000 tons, including lepidolite, petalite, and spodumene. This is the second lithium operation to be built in Brazil. Nuclebras Monzanita e Associados Ltda. owns a lithium chemical plant, but the operation has been closed due to ore supply problems.[7]

Canada.—Tantalum Mining Corp. of Canada Ltd. (TANCO) announced plans to increase its spodumene concentrate capacity to 15,000 tons per year in 1988. The company also considered marketing a new product at its lithium operation in Bernic Lake, Manitoba. An amblygonite-spodumene concentrate containing about 6.5% lithium oxide and 8% to 10% phosphorous pentoxide would be produced as a byproduct of the company's spodumene concentrate. The amblygonite-spodumene concentrate would be targeted for specialty ceramics applications. TANCO also announced plans to resume tantalum production at the same location in 1988.[8]

Chile.—Sociedad Chilena de Litio Ltda., a joint venture between Foote and Corporación de Fomento de la Producción (CORFO), increased production to about 12 million pounds of lithium carbonate. This increase of more than 20% over that of 1986 approached the plant's design capacity of 16 million pounds. Investigations of the feasibility of a second operation at the Salar continued. AMAX Exploration Inc. (United States), CORFO, and Molibdenos y Metales S.A. (Chile) formed a consortium, Minera Salar de Atacama Ltda., to conduct a 3-year evaluation program, which began in 1986.[9]

Yugoslavia.—A lithium battery factory

was built by the Trepca Enterprise in Gnjilane, Vojvodina. The factory, a joint venture with Battery Engineering Inc. of the United States, was planned to produce $3 million worth of batteries per year. Button, cylindrical, and spiral cells will be produced.[10]

Zimbabwe.—A new heavy-medium separation plant was built to recover petalite from a huge stockpile that had previously been considered waste material because it was impossible to separate by means of handpicking.[11] The ore concentrates recovered from the stockpile are expected to be produced with no additional mining expenses.

Table 5.—Lithium minerals and brine: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina (minerals not specified)	168	24	e22	e22	22
Australia, spodumene	1,100	7,200	12,300	e12,100	13,000
Brazil:					
Amblygonite	125	54	130	e165	165
Lepidolite	1				
Petalite	2,086	526	1,458	r,e1,270	1,380
Spodumene	128	317	118	r,e220	220
Canada, spodumene		e90	e330	688	820
Chile, carbonate from subsurface brine		2,326	4,969	4,914	4,960
China (minerals not specified)[e, 3]	16,500	16,500	16,500	16,500	16,500
Namibia:					
Amblygonite	56	67	55	57	55
Lepidolite	34	23	121	57	55
Petalite	770	880	1,984	1,220	1,200
Portugal, lepidolite	601	1,086	143	[4]	
U.S.S.R. (minerals not specified)[e, 3]	60,600	60,600	60,600	60,600	60,600
United States, spodumene and subsurface brine	W	W	W	W	W
Zimbabwe (minerals not specified)	21,157	r24,855	30,765	36,117	37,500

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Table includes data available through Apr. 22, 1988.

[2]In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported and no valid basis is available for estimating production levels.

[3]These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available. Output by China and the U.S.S.R. has never been reported.

[4]Revised to zero.

TECHNOLOGY

The Bureau of Mines conducted research into the recovery of lithium from clays. The McDermitt caldera on the Nevada-Oregon border is estimated to contain more than 3 million tons of lithium. Lithium recovery of over 80% was achieved by limestone-gypsum roasting and selective chlorination techniques. Although the tests were successful, the costs of both processes were considered to be prohibitive. The limestone-gypsum process cost an estimated $2.02 to produce 1 pound of lithium carbonate, and the selective chlorination process costs were estimated at $3.85 per pound of lithium carbonate.[12]

A lithium-iron-sulfide battery developed by Argonne National Laboratories to power street vehicles delivered the equivalent of 200 miles of city driving in a bench-scale test. The test was conducted at a laboratory operated for DOE by the University of Chicago. Researchers have been working since the 1973 energy crisis to develop a battery-powered vehicle that would not require gasoline for its operation. The battery will be road tested in 1988 by the Tennessee Valley Authority in a cargo van adapted for its use.[13]

Research continued to determine the optimum concentration of lithium in aluminum-lithium alloys to minimize density without adversely affecting strength and stability. Scientists at Lawrence Berkeley Laboratory's Center for Advanced Materials were searching for the best materials to use in a proposed "space plane." The space plane is intended to take off from conventional runways and reach orbital speed. The laboratory is operated for DOE by the University of California.[14]

Foote has developed a lithium ceramic consisting of a mixture of lithium aluminate and lithium silicate solutions that hardens at room temperature to form a heat-resistant, ceramic-like material. The material shows compressive strengths of

6,000 (pounds per square inch) when hardened at room temperature. When fired, the strength of the material increases.[15]

Lithium carbonate has been used for decades to treat manic-depressive mental disorders. A study conducted at Ben Gurion University of the Negev, Beersheba, Israel, found that lithium blocks the activity of two types of protein that trigger many types of cell response to outside stimuli.[16]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]Metals Week. Cyprus Dives Into Lithium. V. 58, No. 51, 1987, p. 3.
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